Thin film surface orientation for liquid crystals

EXHIBIT B

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Vacuum-deposited films now replace the familiar "rubbing" process in substrate preparation for liquid-crystal cells. Films deposited at an angle provide an oriented surface for alignment of nematic liquid crystals far better than the well-known "rubbed" plate. The oblique deposit causes a film growth in a preferred direction, which results in a "sympathetic alignment" of the nematic liquid crystals when applied.

Excellent alignment properties have been obtained using obliquely deposited thin films in fabricating liquid-crystal displays. Orientation resulting from the familiar "rubbing" process is now accomplished with more predictable and repeatable results. The new technique involves vacuum depositing films, 100 Å or less, onto substrates at an angle of approximately 85° to the normal.

The angular deposit causes the film to "grow" in a preferred direction. When liquid crystals are subsequently applied to such a substrate, they become "sympathetically aligned" to the direction of film growth.

Electro-optical devices made this way have high contrast and good uniformity. The orientation durability of the film, when deposited in a clean vacuum system below 10^{-5} Torr, seems to be unaffected through normal processing, cleaning, and reprocessing cycles. This is desirable in characterization studies where the same plates may be used over and over again with the same alignment properties. Also, films may be selectively etched using Shipley AZ-111 photoresist in photochemical processing.

The orientation process involves depositing the material, such as gold or silicon monoxide, onto selected clean glass plates at an angle as shown in Fig. 1. Since only a very thin film is required for orientation purposes, the deposited film need not be continuous nor reach the conductive state. In the case of nonconductors such as silicon monoxide, the film need not be insulating. Using familiar vacuum evaporation techniques, at a pressure below 10^{-5} Torr, the film is deposited to a computed thickness of 70 Å.

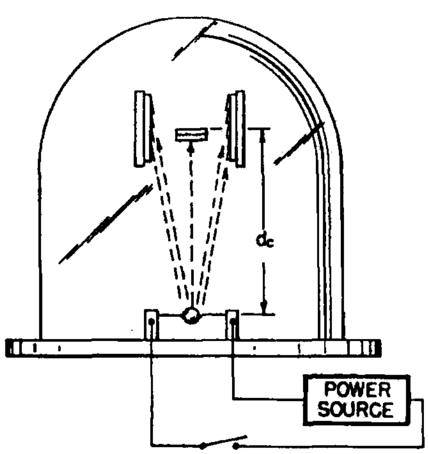
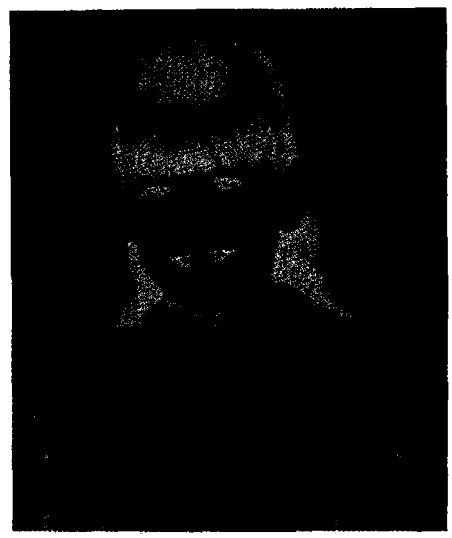


FIG. 1. Bell-jar arrangement for angular deposition. The control substrate is placed in the center of the area.



(a)

(b)

FIG. 2. Liquid-crystal cell with preferential alignment obtained by selective removal of oriented angular film (dot pattern, 133 ×133/in. square). (a) Between crossed polarizers; (b) between aligned polarizers.

Film thickness measurement is made on the control substrate where the deposit arrives perpendicular to the surface. This plate is positioned in the center of the deposition area directly above the source. The thickness of the angular deposit is calculated from the control-plate film thickness, T_c; the distance between source and substrate, d; and the angle of the angular plates, ϕ. For all practical purposes, d can be neglected when small substrates are used and d is large.

The deposition thickness T varies as d^{-2} and is proportional to the cosine of the deposition angle. For the arrangement as shown in Fig. 1, and where d is large compared to substrate dimension, the thickness of the angular-deposited film is

$$T_a = \cos\phi T_c, \tag{1}$$

where T_a is the thickness of the angular-deposited film and T_c the control-plate film thickness.

In a typical example, with measured deposition of 800 Å on the control substrate at a distance d_c, a computed 70-Å film would be deposited obliquely onto the desired substrates at an 85° angle where the distance point $d_a = d_c$. Portions of the substrate where d is greater than d_c will yield a thinner deposit. The importance of making d large should be stressed so that uniformity is obtained over the entire interested region of the substrate. For small substrates such as 2×2 in., a d of 10 in. will give good uniformity.

It is interesting to note that various materials have been angularly deposited with differing results. For example, a copper film will give excellent homeotropic alignment, while chromium, platinum, aluminum, gold, and silicon monoxide align sympathetic to the direction of deposit.

Preferential alignment is demonstrated in Fig. 2, where an angularly deposited film of silicon monoxide has been photochemically processed. Thinned Shipley AZ-111 resist was used, exposed, and developed in the normal manner. The silicon monoxide deposit was then selectively etched by a 1- to 2-sec dip in a 10% HF solution. After this, acetone was used to remove the resist, followed by a methanol rinse. While still wet, the cleaning was continued for 5 min in a Freon TF vapor degreaser.

Only one plate in this cell is photochemically processed. The counterplate is fully oriented and placed at 90° to the etched plate direction in assembly. The liquid crystals therefore are twisted only in those areas between the plates where the orientation film is not etched away in the processed plate.

The cell shown in Fig. 2 incorporates a 0.0003-in. silk-screened glass spacer. The liquid crystals present in this demonstration model were *p*-methoxy-benzylidine—*p*-*n*-butyl-anilene (MBBA).

Catastrophic disruption of the flow of a magnetically confined intense relativistic electron beam

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A disruption in the flow of an intense annular relativistic electron beam occurred when a sudden change in the radius of the drift tube walls was introduced. Experimental results showed that the electron beam (which was immersed in a homogeneous magnetic field) was under the influence of a strong nonadiabatic force which caused considerable changes in beam characteristics, such as spatial distribution and electron transverse energy.

Intense pulsed relativistic electron beams of power $\gtrsim 10^{10}$ W have been used, and suggested for use, in various areas of research, such as thermonuclear fusion,[1-3] microwave generation,[4,5] solid-state physics,[6] and ion acceleration.[7] In general, two problems must be faced by any user of this type of electron beam: (i) generation and (ii) transport. The first of these problems is now thoroughly covered in the literature.[8,9] Beam transport is commonly accomplished in two ways, or by a combination of the two, which are also extensively covered in the literature, both experimentally and theoretically: (i) propagation of the electron beam in a gaseous or a plasma medium,[10,11] and (ii) propagation of the electron beam in an axial magnetic field.[12-14] The magnetically confined mode of propagation has been found to be particularly useful for the production of microwaves[4,5] and for high-efficiency beam transport.[12,13] Theoretical calculations on the importance to such beams of the ratio between the beam and the drift tube wall radii have been performed,[15] and partially verified experimentally.[12] More complete verification is available[16] for similar calculations for beam transport without applied magnetic fields.[17] However, analytical difficulty has precluded any theoretical consideration of the importance of smooth drift tube walls. In this letter we present experimental results demonstrating the profound effect of a sudden change in the radius of the drift tube on the characteristics of a high-power magnetically confined annular relativistic electron beam. The implications to potential users of such beams could be very important.

The experimental system is shown schematically in Fig. 1. The beam source was a high-voltage generator applying a 50-nsec ~600-kV pulse to a "foilless diode",[18] resulting in the emission of an ~15-kA thin annular